EXAM BOOSTER EDITION

CBSE Class 9 Science

Chapter 4: Structure of the Atom

COMPREHENSIVE REVISION PACKAGE

- Important Core Concepts & Postulates
- Bohr-Bury Scheme & Valency Rules
- Top 30 Frequently Repeated Exam Questions
- Top 20 Most Expected Practice Questions
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- New Pattern Assertion & Reason + Case Studies

PERFECT STUDY COMPANION FOR FORMATIVE & SUMMATIVE ASSESSMENTS

SECTION 1: Chapter Overview

What is an Atom?

An atom is the smallest particle of an element that retains the chemical properties of that element. It serves as the fundamental building block of all matter in the universe.

Importance of Studying Atomic Structure

Understanding the internal structure of an atom is crucial as it forms the bedrock for both chemistry and atomic physics. It specifically explains:

- The physical and chemical nature of matter and its varied properties.
- The underlying reasons why elements combine dynamically to form compounds.
- The logical basis behind the arrangement of the periodic table and the mechanisms of chemical reactions.

Learning Outcomes

By the end of this chapter, you will be able to:

- Understand the discovery and distinct physical properties of subatomic particles (electrons, protons, and neutrons).
- Describe, visualize, and critically compare different historical atomic models (Thomson's, Rutherford's, and Bohr's).
- Define and perform numerical calculations regarding the atomic number and mass number.
- Write step-by-step electronic configurations of elements and determine their valency.
- Differentiate between isotopes and isobars, and recognize their essential real-world applications.

Chapter Summary Outline

- **Subatomic Particles:** Atoms are divisible structures composed of three basic units: electrons, protons, and neutrons.
- **Atomic Models:** Evolutionary timeline from Thomson's model (plum pudding) to Rutherford's model (nuclear architecture) and Bohr's model (quantized energy levels).
- **Atomic Number (Z):** Represents the net number of protons residing securely within the nucleus.
- **Mass Number (A):** Relates to the combined total of protons and neutrons (nucleons) present in the nucleus.

- **Electronic Configuration:** The organized distribution of electrons across successive electronic shells (***K, L, M, N...***).
- **Valency:** The fundamental combining capacity of an atom, purely dictated by its outermost valence electrons.
- **Isotopes:** Atoms originating from the same element that share an identical atomic number but differ in mass number.
- **Isobars:** Unique atoms originating from completely different chemical elements that share an identical mass number but possess different atomic numbers.

SECTION 2: Important Concepts

1. Charged Particles in Matter

Definition: Matter is ultimately constructed from basic structural units called atoms, which inherently house charged particles.

Explanation:

- **Protons:** Positively charged (***+1***) particles embedded firmly inside the nucleus.
- **Electrons:** Negatively charged (***-1***) particles orbiting continuously outside the nucleus.
- **Neutrons:** Neutral, uncharged particles sharing space within the dense nucleus alongside protons.

NCERT Point of View: The existence of these counter-balancing charged entities elegantly explains the electrical characteristics of macro-matter and provides context for how atomic interactions occur.

2. Discovery of the Electron

Definition: The electron is the stable, fundamental negatively charged subatomic component of an atom.

Explanation: Discovered masterfully by J.J. Thomson in 1897 through a series of meticulous experiments utilizing a customized high-vacuum cathode ray tube.

Properties:

- **Absolute Charge:** -1.6×10^{-19} C
- **Rest Mass:** 9.11×10^{-31} kg (approximately evaluated to be a tiny fraction, ***1/2000***, of a standard proton's mass).

> **IMPORTANT EXAM NOTE:** Questions tracking the design, observations, and conclusions of the cathode ray tube experiment frequently appear in school examinations.

3. Discovery of the Proton

Definition: The proton is a robust, positively charged subatomic constituent found within the core of all atoms.

Explanation: E. Goldstein in 1886 identified positive ion streams moving in a discharge tube using a modified perforated cathode layout.

Properties:

- **Absolute Charge:** $+1.6 \times 10^{-19}$ C

- **Rest Mass:** 1.67×10^{-27} ***kg*** (assigned a relative value of ***1 u***).

> **IMPORTANT EXAM NOTE:** These positive streams were initially documented as "Canal Rays," the investigation of which eventually paved the way for identifying individual protons.

4. Discovery of the Neutron

Definition: An uncharged subatomic particle with mass slightly greater than that of a proton.

Explanation: Tracked down and confirmed by James Chadwick in 1932 by bombarding light elements with highly energetic alpha particles.

Properties: Net charge is exactly zero (***0***). Mass is considered approximately equivalent to that of a proton (***1 u***).

> **IMPORTANT EXAM NOTE:** Neutrons populate the atomic nuclei of absolutely all elements with the single notable exception of Ordinary Hydrogen (Protium).

5. Thomson's Model of the Atom

Definition: The initial early structural paradigm stating an atom is a uniform sphere of positive charge containing embedded electrons.

Explanation: Thomson proposed an atomic framework visually analogous to a traditional Christmas pudding or a sliced watermelon. The structural red flesh represents the spread-out positive field, whereas the seeds represent the stationary embedded electrons. The equal magnitude of these charges guarantees macroscopic electrical neutrality.

> **IMPORTANT EXAM NOTE:** This model was quickly discarded as it offered no mechanism for overall atomic stability and failed completely to justify Rutherford's later gold foil scattering data.

6. Rutherford's Nuclear Model

Definition: A revolutionary atomic configuration derived from tracking the scattering behaviors of highly energetic helium nuclei passing through thin sheets of metal.

Explanation: High-speed alpha particles (He^{2+}) were aimed at an extremely thin piece of gold foil. The dramatic results showed:

- The vast majority of particles traveled straight through without experiencing any tracking adjustments.
- A small, measurable fraction suffered minor directional deflections.
- An extremely rare count (nearly 1 in 12,000) bounced directly backward along their incoming path.

Rutherford concluded that the atom features a minute, incredibly dense, and positively charged central core called the **nucleus**, surrounded by vast regions of completely empty space containing fast-moving electrons.

7. Bohr's Refined Atomic Model

Definition: A sophisticated structural design introduced by Niels Bohr incorporating basic quantum principles to rescue the flawed classical physics interpretation of Rutherford's model.

Postulates:

1. Electrons move only in highly specific, non-radiating paths termed *discrete orbits* or primary *energy levels*.
2. While orbiting inside these specific, stationary states, electrons do not release or radiate electromagnetic energy.
3. Energy transitions occur only when an electron actively jumps from one permitted orbit to another, absorbing or emitting a photon of precise energy.

8. Atomic Number (Z)

Definition: The precise sum of protons packed inside the nucleus of an atom, establishing the identity of that element.

$$Z = ext\{Number of Protons\}$$

In any perfectly neutral atom, the count of protons is invariably equal to the count of circulating electrons. For instance, Oxygen ($Z = 8$) possesses exactly 8 protons and 8 electrons.

9. Mass Number (A)

Definition: The integrated sum representing the total quantities of both protons and neutrons combined inside the nuclear core.

$$A = ext\{Number of Protons\} (Z) + ext\{Number of Neutrons\} (n)$$

For example, an Ordinary Aluminum atom containing 13 protons and 14 neutrons is specified by a mass number of $A = 27$.

10. Electronic Configuration & Bohr-Bury Scheme

Definition: The systemic, rule-governed arrangement of an element's electron population across available concentric shells.

Core Rules:

- The maximum carrying capacity of any shell number n is calculated via the formula: $2n^2$.
  - K Shell ($n = 1$): Max 2 electrons
  - L Shell ($n = 2$): Max 8 electrons
  - M Shell ($n = 3$): Max 18 electrons

    - N Shell ($n = 4$): Max 32 electrons
- The absolute outermost valence shell cannot host more than 8 electrons under stable conditions.
- Shells must fill in a strict, stepwise progression; inner shells must be saturated before subsequent outer layers accept electrons.

11. Valency

Definition: The intrinsic chemical combining capacity of an atom, dictated by the number of valence electrons.

Operational Rule:

- If Outer Electrons ≤ 4: $ext{Valency} = ext{Number of Valence Electrons}$
- If Outer Electrons > 4: $ext{Valency} = 8 - ext{Number of Valence Electrons}$

Examples: Magnesium ($Z = 12$, arrangement: 2, 8, 2) has 2 outer electrons, so its valency is 2. Nitrogen ($Z = 7$, arrangement: 2, 5) has 5 outer electrons, making its calculated valency $8 - 5 = 3$.

12. Isotopes

Definition: Variants of a particular chemical element that exhibit the identical atomic number but possess differing mass numbers due to neutron variations.

Examples: Hydrogen exists as Protium (${}^{1}{}_{1}H$), Deuterium (${}^{2}{}_{1}H$), and Tritium (${}^{3}{}_{1}H$). Carbon is found as Carbon-12 (${}^{12}{}_{6}C$) and radioactive Carbon-14 (${}^{14}{}_{6}C$).

13. Important Applications of Isotopes

- **Uranium-235:** Serves as primary fissile fuel inside commercial nuclear power reactors.
- **Cobalt-60:** Extensively deployed in high-energy radiotherapy for cancer treatment.
- **Iodine-131:** Routinely used to diagnose and treat critical thyroid disorders like goitre.
- **Carbon-14:** Utilized in archaeological labs for carbon dating to determine fossil age.

14. Isobars

Definition: Completely unique elemental species that share an identical mass number but are distinguished by different atomic numbers.

Example: Calcium (${}^{40}{}_{20}Ca$) and Argon (${}^{40}{}_{18}Ar$). They maintain matching total nucleon counts ($A = 40$) despite belonging to separate chemical elements with distinct atomic structures.

SECTION 3: Top 30 Frequently Repeated Questions

Very Short Answer Type (1 Mark)

Q1. What is an atom?

> Ans: An atom is the smallest particle of an element that completely retains the distinct chemical properties of that specific element.

Q2. Who discovered the neutron?

> Ans: The neutron was discovered by physicist James Chadwick in the year 1932.

Q3. What is the charge and mass of an electron?

> Ans: An electron carries a relative charge of -1 (absolute: -1.6×10^{-19} C) and its rest mass is negligible, roughly ***1/2000*** of a standard proton's mass.

Q4. What are canal rays?

> Ans: Canal rays are streams of positively charged gaseous ions that move towards the negative electrode in a discharge tube, leading directly to the discovery of the proton.

Q5. Define atomic number.

> Ans: Atomic number is defined as the total number of protons present inside the nucleus of an element's atom.

Q6. What is the maximum number of electrons that can be accommodated in the M-shell?

> Ans: According to the $2n^2$ rule, for the M-shell ($n=3$), the maximum limit is $2(3)^2 = 18$ electrons.

Q7. Define valency.

> Ans: Valency is defined as the fundamental combining capacity of an atom of an element during chemical combinations.

Q8. What is an octet?

> Ans: An octet is a stable electronic configuration consisting of exactly 8 electrons in the outermost valence shell of an atom.

Q9. Why is an atom electrically neutral?

> Ans: An atom is neutral because it contains an exactly equal number of positively charged protons and negatively charged electrons, neutralizing the overall charge.

Q10. What are isotopes?

> Ans: Isotopes are atoms of the same chemical element that possess the same atomic number but differ in their mass numbers.

Short Answer Type (2-3 Marks)

Q11. What are the postulates of Thomson's atomic model?

> Ans: The main postulates are:
> (i) An atom consists of a uniformly distributed sphere of positive charge.
> (ii) Negatively charged electrons are embedded directly into this positive sphere.
> (iii) The negative and positive charges are perfectly equal in magnitude, making the atom electrically neutral.

Q12. What are the limitations of Rutherford's model of the atom?

> Ans: Rutherford's model failed to clarify atomic stability. According to classical electromagnetic theory, any charged particle moving in a circular path must accelerate and continuously radiate energy. If an electron did this, it would lose velocity, spiral inward, and eventually crash into the nucleus, making atoms highly unstable. However, real atoms are perfectly stable.

Q13. State the main postulates of Bohr's model of an atom.

> Ans: The core postulates are:
> (i) Electrons revolve around the central nucleus only in specific, non-radiating permitted circular paths called discrete energy shells or orbits.
> (ii) These paths are stationary states, meaning electrons do not shed energy while revolving in them.
> (iii) Electrons change their energy states only when jumping between levels, emitting or absorbing a specific photon of energy.

Q14. Write the rules for the distribution of electrons in various shells.

> Ans: Following the Bohr-Bury scheme:
> (i) The maximum capacity of a shell is given by $2n^2$ where n is the shell index.
> (ii) The outermost valence shell can hold a maximum of 8 electrons.
> (iii) Orbits are filled step-by-step; inner shells must be fully saturated before outer ones can start filling.

Q15. Calculate the number of protons, electrons, and neutrons in a chlorine atom with Z=17 and A=35.

> Ans: Given: Atomic number (Z) = 17, Mass number (A) = 35.
> • Number of Protons = $Z = 17$
> • Number of Electrons = Protons = 17 (since it is a neutral atom)
> • Number of Neutrons = $A - Z = 35 - 17 = 18$.

Q16. Define isotopes and isobars with examples.

Ans:

• **Isotopes:** Atoms of the same element with identical atomic numbers but different mass numbers. Example: Carbon-12 ($^{12}_{6}C$) and Carbon-14 ($^{14}_{6}C$).

• **Isobars:** Atoms of completely different elements with different atomic numbers but the same mass number. Example: Argon ($^{40}_{18}Ar$) and Calcium ($^{40}_{20}Ca$).

Q17. Why do isotopes have similar chemical properties?

Ans: Chemical properties are dictated by the total count of valence electrons and the resulting electronic configuration. Because isotopes of an element share an identical atomic number, they have identical electronic configurations and valence counts, which makes their chemical behaviors virtually identical.

Q18. What are the applications of isotopes?

Ans: Key applications include:

(i) Uranium-235 is deployed as fuel in nuclear fission power plants.

(ii) Cobalt-60 is used in targeted radiation therapies to treat cancer.

(iii) Iodine-131 is used in medical procedures to manage thyroid conditions.

(iv) Carbon-14 is standardly applied in carbon-dating fossil specimens.

Q19. If an atom has 8 electrons and 8 protons: (i) What is its atomic number? (ii) What is its net charge?

Ans:

(i) Its atomic number is 8, since atomic number (Z) is defined by the number of protons.

(ii) The net charge is 0 (electrically neutral) because the positive proton charge (+8) balances out the negative electron charge (-8).

Q20. What is the electronic configuration of sodium (Na) and chlorine (Cl)?

Ans:

• Sodium ($Z=11$): The distribution across shells is K=2, L=8, M=1 (written as 2, 8, 1).

• Chlorine ($Z=17$): The distribution across shells is K=2, L=8, M=7 (written as 2, 8, 7).

SECTION 4: Top 20 Most Expected Questions

Q1. Describe Rutherford's alpha-particle scattering experiment. What observations led him to discover the nucleus?

> Ans: Rutherford bombarded a highly malleable, 1000-atoms-thick gold foil using high-velocity, doubly-charged helium ions (alpha particles).
> **Observations:**
> (i) Over 99% of the alpha particles passed clean through the gold layer without showing any deflection.
> (ii) A small fraction experienced marginal, small-angle deflections.
> (iii) An exceptionally small count (around 1 in 12,000) was repelled directly back at 180 degrees.
> **Conclusion:** The major rebounding effects indicated that all the positive charge and nearly the entire mass of the gold atom must be packed tightly inside a tiny, extremely heavy center called the nucleus.

Q2. Explain Bohr's model of an atom. How did it explain the stability of an atom?

> Ans: Niels Bohr stated that electrons reside only inside fixed, quantized circular paths designated as stationary orbits or principal energy shells (K, L, M, N). **Stability Explanation:** Because these paths represent fixed energy levels, an electron moving within its allowed path cannot lose energy through radiation. Since it does not bleed energy, it never spirals inward toward the nucleus, ensuring the atom remains structurally stable.

Q3. What is the difference between the atomic number and the mass number?

> Ans:
> • **Atomic Number (Z):** The exact count of protons residing in the nucleus. It is unique to each element and determines its identity.
> • **Mass Number (A):** The collective sum of both protons and neutrons located inside the nuclear shell. It represents the approximate total atomic mass.

Q4. How is the valency of an element determined? Explain with the help of examples.

> Ans: Valency is determined by observing the outer valence shell electron population:
> • If outer electrons are 1 to 4, valency matches that number. *Example:* Silicon (2, 8, 4) has 4 valence electrons, yielding a valency of 4.
> • If outer electrons exceed 4, valency is calculated by subtracting that count from 8. *Example:* Oxygen (2, 6) has 6 valence electrons, yielding a valency of ***8 - 6 = 2***.

Q5. Distinguish between isotopes and isobars with examples.

> Ans:
> • **Isotopes:** Share the same atomic number but possess different mass numbers. Example: Protium ($^{1}_{1}H$) and Deuterium ($^{2}_{1}H$). They have identical chemical properties.
> • **Isobars:** Possess different atomic numbers but share the exact same mass number. Example: $^{40}_{20}Ca$ and $^{40}_{18}Ar$. They exhibit entirely different chemical properties.

Q6. Give the electronic configuration of an element with atomic number 12. What is its valency? Name the element.

> Ans: The electronic configuration for atomic number 12 is 2, 8, 2. Since it has 2 valence electrons, its valency is 2. The element is Magnesium (Mg).

Q7. What would be the observation if Rutherford used a foil of a metal other than gold?

> Ans: The overall trend of observations would remain similar because all atomic structures follow the same general pattern (mostly empty space with a central core). However, if a metal with a lower atomic number (fewer protons) were substituted, the positive nuclear charge would be weaker, resulting in fewer and less dramatic large-angle deflections.

Q8. Describe the discovery of the electron.

> Ans: J.J. Thomson passed high-voltage electricity through a gas at ultra-low pressure inside a discharge tube. He observed rays emerging from the cathode that traveled toward the anode. These rays were deflected by external electric and magnetic fields toward the positive plate, proving they consisted of stream-like, negatively charged subatomic particles named electrons.

Q9. Describe the discovery of the proton.

> Ans: E. Goldstein used a perforated negative cathode plate in a gas discharge tube experiment. He noticed distinct luminous rays moving in the opposite direction of the cathode rays. Because these traveled through the cathode channels toward the negative zone, they were identified as positive ion streams, named Canal Rays, which later established the existence of the proton.

Q10. An element X has 6 protons, 6 electrons, and 6 neutrons. Write its atomic number and mass number.

> Ans: Atomic Number (Z) = Protons = 6. Mass Number (A) = Protons + Neutrons = $6 + 6 = 12$.

Q11. Why do noble gases have zero valency?

> Ans: Noble gases possess a completely filled valence shell (an outer octet of 8 electrons, or a stable duet of 2 in Helium). Because their valence shells are stable, they have no chemical tendency to lose, gain, or share electrons, giving them a combining capacity of zero.

Q12. What are the limitations of J.J. Thomson's model of the atom?

> Ans: (i) It could not explain the high-angle scattering paths of alpha particles observed in Rutherford's gold foil experiment. (ii) It lacked any underlying mathematical or experimental basis. (iii) It offered no physical mechanism to separate opposing charges, failing to explain how the atom remains stable.

Q13. If an atom has 11 protons, 12 neutrons, and 11 electrons, what is its atomic number and mass number?

> Ans: Atomic Number (Z) = 11 (number of protons). Mass Number (A) = Protons + Neutrons = $11 + 12 = 23$ (This element is Sodium).

Q14. What is the significance of the atomic number?

> Ans: The atomic number is the fundamental identifier of an element. It determines the total electron count of a neutral atom, which dictates the electronic configuration and chemical properties of the element. No two different elements share the same atomic number.

Q15. What is an ion?

> Ans: An ion is an electrically charged chemical species formed when a neutral atom either loses valence electrons (forming a positive cation, e.g., Na^+) or gains valence electrons (forming a negative anion, e.g., Cl^-).

Q16. What is the charge on an atom that has 7 protons and 9 electrons?

> Ans: Net Charge = (Total Protons × Positive Unit Charge) + (Total Electrons × Negative Unit Charge) = $(+7) + (-9) = -2$. The resulting particle is an anion with a net charge of -2.

Q17. What are the three fundamental sub-atomic particles of an atom?

> Ans: The three fundamental particles are the Electron (negatively charged), the Proton (positively charged), and the Neutron (electrically neutral).

Q18. Why is the mass of an electron not included in the mass number?

> Ans: An electron's mass is tiny (approx. 9.1×10^{-31} kg), which is roughly $1/2000$ of a proton's mass. Because it is negligible compared to the heavy core particles, it does not significantly affect the total atomic mass calculation.

Q19. What are nucleons?

> Ans: Subatomic particles that reside within the boundary of the atomic nucleus—specifically protons and neutrons—are collectively referred to as nucleons.

Q20. What happens to the stability of an atom when an electron jumps from a higher orbit to a lower orbit?

> Ans: When an electron drops into a lower, more inward orbit, it sheds excess potential energy by emitting radiation. By transitioning into a lower energy state, the atom reaches a more stable configuration.

SECTION 5: NCERT-Based Questions

NCERT Back Exercise & Intext Solutions

Q1. Compare the properties of electrons, protons, and neutrons.

Ans: A detailed comparative breakdown reveals:

Feature	Electron (e^-)	Proton (p^+)	Neutron (n)
Relative Charge	Negative (-1)	Positive (+1)	Neutral (0)
Relative Mass	Negligible (~1/2000 u)	1 u	1 u
Location	Outside the nucleus	Inside the nucleus	Inside the nucleus
Discoverer	J.J. Thomson	E. Goldstein	James Chadwick

Q2. What are the limitations of J.J. Thomson's model of the atom?

Ans: Thomson's model could not clarify how the positive charge holds the negative electrons in place to maintain overall structural stability. It was also completely contradicted by Rutherford's gold foil scattering experiment, which showed that the positive charge is concentrated in a tiny central core rather than spread uniformly throughout the atom.

Q3. What are the limitations of Rutherford's model of the atom?

Ans: The main limitation was its conflict with classical electrodynamics. An electron revolving around a nucleus moves in a curved, accelerated path and should continuously emit electromagnetic radiation. This loss of energy would slow down the electron, causing it to spiral inward and crash into the nucleus. This contradicts the observed stability of matter, as real atoms do not collapse.

Q4. Describe Bohr's model of the atom.

Ans: Niels Bohr proposed that electrons move around the nucleus only in specific, non-radiating paths called discrete orbits or energy levels (labeled K, L, M, N or n=1, 2, 3, 4). While an electron remains in one of these allowed orbits, its energy is quantized and remains constant, meaning it does not lose energy by radiation. Energy is only absorbed or emitted when an electron moves from one energy level to another.

Q5. Summarise the rules for writing the distribution of electrons in various shells for the first eighteen elements.

> Ans: The electron distribution follows the Bohr-Bury scheme:
> (i) The maximum number of electrons in any shell is determined by the formula $2n^2$, where n is the shell number.
> (ii) The outermost shell cannot hold more than 8 electrons, even if its theoretical capacity is higher.
> (iii) Electrons fill the shells in a stepwise manner, meaning inner shells must be fully occupied before electrons can begin filling the next outer shell.

Q6. Define valency by taking examples of silicon and oxygen.

> Ans: Valency is the chemical combining capacity of an atom, determined by the number of valence electrons in its outermost shell.
> • **Silicon:** Atomic number 14, electronic configuration 2, 8, 4. It has 4 valence electrons, so its valency is equal to 4.
> • **Oxygen:** Atomic number 8, electronic configuration 2, 6. It has 6 valence electrons. Since this exceeds 4, its valency is calculated as $8 - 6 = 2$.

Q7. Explain with examples: (i) Atomic number, (ii) Mass number, (iii) Isotopes and (iv) Isobars. Give any two uses of isotopes.

> Ans:
> (i) **Atomic Number:** The number of protons in an atom's nucleus. Example: Carbon has 6 protons, so its atomic number is 6.
> (ii) **Mass Number:** The total number of protons and neutrons in the nucleus. Example: Carbon-12 has 6 protons and 6 neutrons, giving it a mass number of 12.
> (iii) **Isotopes:** Atoms of the same element with the same atomic number but different mass numbers. Example: ${}^{12}_{6}C$ and ${}^{14}_{6}C$.
> (iv) **Isobars:** Atoms of different elements with the same mass number but different atomic numbers. Example: ${}^{40}_{20}Ca$ and ${}^{40}_{18}Ar$.
> **Two Uses of Isotopes:** (1) Cobalt-60 is used in radiotherapy for cancer treatment. (2) Uranium-235 is used as a fuel in nuclear reactors.

Q8. Na^+ has completely filled K and L shells. Explain.

> Ans: A neutral Sodium atom (Na) has an atomic number of 11 and an electronic configuration of 2, 8, 1. To achieve a stable octet, it loses its single outermost valence electron, forming a Sodium ion (Na^+). This leaves the ion with a total of 10 electrons distributed as K=2 and L=8. Since the maximum capacities of the K shell (2) and L shell (8) are reached, both shells are completely filled.

Q9. If bromine atom is available in the form of two isotopes, ^{79}Br (49.7%) and ^{81}Br (50.3%), calculate the average atomic mass of the bromine atom.

> Ans: The average atomic mass is calculated by finding the weighted average based on isotopic abundance:
>
> $$\text{Average Mass} = \left(79 \times \frac{49.7}{100}\right) + \left(81 \times \frac{50.3}{100}\right)$$
>
> $$\text{Average Mass} = 39.263 + 40.743 = 80.006 \text{ u}$$
>
> The average atomic mass of bromine is approximately **80 u**.

Q10. The average atomic mass of a sample of an element X is 16.2 u. What are the percentages of isotopes ^{16}X and ^{18}X in the sample?

> Ans: Let the percentage abundance of the ^{18}X isotope be $y\%$. This means the percentage abundance of the ^{16}X isotope is $(100 - y)\%$.
> Using the weighted average formula:
>
> $$\frac{18 \times y + 16 \times (100 - y)}{100} = 16.2$$
>
> $$18y + 1600 - 16y = 1620$$
>
> $$2y = 20 \implies y = 10\%$$
>
> Therefore, the abundance of the **^{18}X isotope is 10%**, and the abundance of the **^{16}X isotope is 90%**.

Q11. If Z = 3, what would be the valency of the element? Also, name the element.

> Ans: An atomic number of $Z = 3$ means the neutral atom has 3 protons and 3 electrons. Its electronic configuration is 2, 1. Since it has 1 electron in its outermost shell, its valency is 1. The element is **Lithium (Li)**.

Q12. Composition of the nuclei of two atomic species X and Y is given as under: X: Protons = 6, Neutrons = 6; Y: Protons = 6, Neutrons = 8. Give the mass numbers of X and Y. What is the relation between the two species?

> Ans:
> • Mass Number of X = Protons + Neutrons = $6 + 6 = 12$.
> • Mass Number of Y = Protons + Neutrons = $6 + 8 = 14$.
> **Relationship:** Because both species X and Y share the same atomic number (6 protons) but have different mass numbers (12 and 14), they are **isotopes** of the same element (Carbon).

SECTION 6: Assertion & Reason Questions

Directions: In the following questions, a statement of Assertion (A) is followed by a statement of Reason (R). Choose the correct option: (a) Both A and R are true and R is the correct explanation of A. (b) Both A and R are true but R is not the correct explanation of A. (c) A is true but R is false. (d) A is false but R is true.

Q1. Assertion (A): Thomson's model of an atom failed to explain the stability of the atom.
Reason (R): In Thomson's model, the positive and negative charges were not distributed uniformly.

> **Ans: (c) A is true, but R is false.** Thomson's model explicitly stated that the positive charge was distributed uniformly throughout the sphere. It failed because it could not explain the scattering results of Rutherford's experiment or provide a clear mechanism for stability.

Q2. Assertion (A): Rutherford's alpha particle scattering experiment led to the discovery of the nucleus.
Reason (R): Most of the alpha particles passed straight through the gold foil.

> **Ans: (b) Both A and R are true, but R is not the correct explanation of A.** While both statements are true, the discovery of the nucleus was deduced from the small fraction of alpha particles that suffered large-angle deflections and rebounded, not from the particles that passed straight through.

Q3. Assertion (A): Electrons revolve around the nucleus in fixed orbits as per Bohr's model.
Reason (R): Electrons lose energy continuously while revolving in these fixed orbits.

> **Ans: (c) A is true, but R is false.** According to Bohr's postulates, the orbits are stationary states where electrons do *not* lose energy, which explains why the atom remains stable.

Q4. Assertion (A): Isotopes of an element have the same chemical properties.
Reason (R): Isotopes have the same number of electrons, and chemical properties depend on electronic configuration.

> **Ans: (a) Both A and R are true, and R is the correct explanation of A.** Isotopes have identical atomic numbers and electron distributions, which directly results in identical chemical behavior.

Q5. Assertion (A): Isobars have different chemical properties.
Reason (R): Isobars have different atomic numbers and different numbers of electrons.

> **Ans: (a) Both A and R are true, and R is the correct explanation of A.** Since isobars are elements with different atomic numbers, they have different electronic configurations, which leads to completely different chemical properties.

Q6. Assertion (A): The mass number of an atom is always greater than its atomic number.
Reason (R): Mass number is the sum of protons and neutrons, while atomic number is the number of protons only.

> **Ans: (d) A is false but R is true.** The assertion is technically false because for the ordinary Hydrogen atom (Protium), there are no neutrons, making its atomic number and mass number equal (both are 1). The reason correctly defines both terms.

Q7. Assertion (A): The outermost shell of an atom can have a maximum of 8 electrons.
Reason (R): The formula $2n^2$ determines the maximum number of electrons in any shell.

> **Ans: (b) Both A and R are true, but R is not the correct explanation of A.** Both statements are valid chemical principles, but the outermost limit of 8 electrons (the octet rule) is a specific requirement for stability that is independent of the general $2n^2$ capacity formula.

Q8. Assertion (A): Oxygen has a valency of 2.
Reason (R): Oxygen has 6 electrons in its outermost shell and needs 2 more electrons to complete its octet.

> **Ans: (a) Both A and R are true, and R is the correct explanation of A.** Oxygen's configuration is 2, 6. Because it requires 2 electrons to fill its outer shell, its combining capacity (valency) is $8 - 6 = 2$.

Q9. Assertion (A): The nucleus of an atom is positively charged.
Reason (R): The nucleus contains protons, which are positively charged, and neutrons, which are neutral.

> **Ans: (a) Both A and R are true, and R is the correct explanation of A.** The net positive charge of the nucleus comes from its protons, as the neutrons carry no charge and do not offset the positive charge.

Q10. Assertion (A): A neutral atom contains an equal number of protons and electrons.
Reason (R): Atoms are electrically neutral because they have an equal number of positive and negative charges.

> **Ans: (a) Both A and R are true, and R is the correct explanation of A.** The equal number of positive protons and negative electrons balances out the charges, resulting in a net neutral atom.

Q11. Assertion (A): A neutron is neutral.
Reason (R): A neutron is formed by the combination of a proton and an electron.

> **Ans: (c) A is true, but R is false.** A neutron is an independent elementary subatomic particle with no net charge. It is not a composite particle formed by combining a proton and an electron.

Q12. Assertion (A): The electronic configuration of sodium ion (Na^+) is 2, 8.
Reason (R): Sodium atom loses one electron to form a sodium ion.

> **Ans: (a) Both A and R are true, and R is the correct explanation of A.** Sodium has an atomic number of 11 (2, 8, 1). Losing its single valence electron leaves it with 10 electrons, giving the Na^+ ion a configuration of 2, 8.

Q13. Assertion (A): The electron distribution 2, 8, 9, 1 for an atom is wrong.
Reason (R): The M-shell can have a maximum of 8 electrons.

> **Ans: (c) A is true, but R is false.** The distribution is incorrect because the inner M-shell cannot begin holding 9 electrons while the outer shell has only 1. However, the reason is false because the M-shell has a maximum capacity of 18 electrons, not 8.

Q14. Assertion (A): Rutherford selected gold foil for his experiment because it is highly malleable.
Reason (R): Gold can be hammered into a very thin sheet that is only a few atoms thick.

> **Ans: (a) Both A and R are true, and R is the correct explanation of A.** Rutherford required an extremely thin layer of matter to observe alpha particle scattering without significant absorption, making highly malleable gold the ideal choice.

Q15. Assertion (A): The average atomic mass of chlorine is 35.5 u.
Reason (R): Chlorine has two isotopes, ^{35}Cl and ^{37}Cl, in the ratio 3:1.

> **Ans: (a) Both A and R are true, and R is the correct explanation of A.** Finding the weighted average of the isotopes based on their 3:1 ratio yields: ***rac{35 imes 3 + 37 imes 1}{4} = 35.5 ext{ u}***, which explains the fractional mass.

SECTION 7: Case Study Questions

Case Study 1: Rutherford's Gold Foil Scattering Experiment

Ernest Rutherford performed an experiment by bombarding an extremely thin gold foil with high-velocity alpha particles. He observed that most of the alpha particles passed straight through the foil, a few were deflected at small angles, and a very small number bounced back along their path. Based on these observations, Rutherford challenged Thomson's model and proposed a new nuclear model for the atom.

Q1. What is the nature and charge of alpha particles?

> Ans: Alpha particles are doubly charged Helium ions (He^{2+}). They contain 2 protons and 2 neutrons, giving them a net positive charge of +2 and a mass of 4 u.

Q2. Why did most of the alpha particles pass straight through the gold foil without deflection?

> Ans: This observation indicated that the vast majority of the space inside an atom is empty.

Q3. What did Rutherford conclude from the deflection of a few alpha particles at small angles?

> Ans: It showed that the positive charge inside the atom is not spread out uniformly, but is concentrated in a centralized region that repels passing positive alpha particles.

Q4. What did the observation of a few alpha particles bouncing back indicate?

> Ans: It indicated that the central positive region, called the nucleus, is very small, dense, and contains nearly the entire mass of the atom.

Q5. What was the major drawback of Rutherford's nuclear model?

> Ans: It could not explain atomic stability within classical physics, as accelerating revolving electrons should continuously radiate energy and collapse into the nucleus.

Case Study 2: Bohr's Atomic Orbit Framework

Niels Bohr introduced a refined model to resolve the stability limitations of Rutherford's framework. He suggested that electrons revolve around the central nucleus only in specific, fixed circular paths called discrete orbits or energy levels. He also stated that as long as an electron stays within its allowed orbit, it does not radiate energy, keeping the atom stable.

Q1. What are the fixed orbits in Bohr's model called?

> Ans: They are called stationary orbits, discrete shells, or principal energy levels, often designated as K, L, M, N...

Q2. Why do electrons not lose energy while revolving in Bohr's model?

> Ans: Because these allowed orbits represent stationary energy states where classical electromagnetic radiation rules do not apply to the electron.

Q3. What happens when an electron transitions or jumps from a higher energy level to a lower one?

> Ans: The electron releases its excess energy by emitting radiation or a photon of light with a precise wavelength.

Q4. How did Bohr's model successfully explain the stability of the atom?

> Ans: By postulating that electrons in permitted orbits cannot lose energy continuously, it showed that they maintain their paths and do not spiral into the nucleus.

Q5. Why are the orbits in Bohr's model described as quantized?

> Ans: Because electrons can only exist in specific orbits with fixed, distinct energy values, and are strictly restricted from occupying any intermediate space between these shells.

Case Study 3: Practical Dynamics of Isotopes and Isobars

Atoms of the same element having the same atomic number but different mass numbers are called isotopes. In contrast, atoms of different elements having the same mass number but different atomic numbers are called isobars. Due to their electron configurations, isotopes exhibit identical chemical properties, whereas isobars show entirely different chemical behaviors.

Q1. What are isotopes? Provide a standard example.

> Ans: Isotopes are atoms of the same element with identical atomic numbers but different mass numbers. Example: Carbon-12 ($^{12}_{6}C$) and Carbon-14 ($^{14}_{6}C$).

Q2. What are isobars? Provide a standard example.

> Ans: Isobars are atoms of different elements with the same mass number but different atomic numbers. Example: Calcium ($^{40}_{20}Ca$) and Argon ($^{40}_{18}Ar$).

Q3. Why do isotopes exhibit identical chemical properties?

> Ans: Chemical properties depend on the number of valence electrons and the electronic configuration. Since isotopes have the same atomic number, their electron arrangements match perfectly, leading to identical chemical behavior.

Q4. Why do isobars possess entirely distinct chemical properties?

> Ans: Isobars have different atomic numbers, meaning they have different numbers of protons and electrons. This results in completely different electronic configurations and valence properties, which leads to distinct chemical behavior.

Q5. State one important medical or analytical application of the Carbon-14 isotope.

> Ans: Carbon-14 is widely used in radiocarbon dating to estimate the age of ancient organic fossils and archaeological remains.

SECTION 8: Numericals

Q1. Find the atomic number and mass number of an atom containing 9 protons, 10 neutrons, and 9 electrons.

> Ans:
>
> • Atomic Number (Z) = Number of Protons = **9**
>
> • Mass Number (A) = Protons + Neutrons = $9 + 10 = 19$
>
> (The element is Fluorine).

Q2. An atom has an atomic number of 12 and a mass number of 24. Find its total number of protons, electrons, and neutrons.

> Ans:
>
> • Number of Protons = Atomic Number = **12**
>
> • Number of Electrons = Protons = **12** (since it is a neutral atom)
>
> • Number of Neutrons = Mass Number (A) - Atomic Number (Z) = $24 - 12 = 12$.

Q3. Calculate the total number of protons, electrons, and neutrons present inside an atom of Chlorine represented as $^{35}Cl_{17}$.

> Ans: From the symbol $^{35}_{17}Cl$, we have Atomic Number (Z) = 17 and Mass Number (A) = 35.
>
> • Protons = $Z = 17$
>
> • Electrons = **17** (neutral atom)
>
> • Neutrons = $A - Z = 35 - 17 = 18$.

Q4. Calculate the total number of protons, electrons, and neutrons present inside an atom of Calcium represented as $^{40}Ca_{20}$.

> Ans: From the symbol $^{40}_{20}Ca$, we have Atomic Number (Z) = 20 and Mass Number (A) = 40.
>
> • Protons = **20**
>
> • Electrons = **20**
>
> • Neutrons = $A - Z = 40 - 20 = 20$.

Q5. An element has an electronic configuration of 2, 8, 8, 1. Determine its atomic number, its valency, and its mass number if its nucleus contains 20 neutrons.

> Ans:
>
> • **Atomic Number (Z):** Total electrons in neutral state = $2 + 8 + 8 + 1 = 19$ (The element is Potassium).
>
> • **Valency:** It has 1 electron in its outermost shell, so its valency is **1**.
>
> • **Mass Number (A):** Protons (Z) + Neutrons = $19 + 20 = 39$.